

Statistical Study of Observed and Intrinsic Durations among *BATSE* and *Swift/BAT* GRBs

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Abstract

Studies of *BATSE* bursts (Kouveliotou et al. 1993) have resulted in the widespread adoption of a two-group categorization: long bursts (those with durations ≥ 2 seconds) and short bursts (those with durations ≤ 2 seconds). This categorization, one must recall, used the observed T_{90} time durations for bursts (during which 90% of a burst's fluence is measured).

In this work, we have explored two ideas: 1) a statistical search for a possible third, intermediate category of bursts (between the “short” and the “long” ones) among 2041 *BATSE* GRBs and 757 *Swift/BAT* ones; 2) a study of bursts' intrinsic durations, where durations in the bursts' reference frames (instead of the observed durations) are considered; for this, 248 *Swift/BAT* bursts that have redshift measurements were statistically analyzed for the same categorization goal.

We first use a Monte Carlo method to determine the proper binning of each GRB, considering that bursts come with different uncertainties on their durations. Then, using the method of minimization of chi-square χ^2 , we search for the best fit of the normalized frequency distributions $\frac{1}{N_0} \frac{dN}{d \ln T}$ of durations; this allows us to compare fits with two groups (“short” and “long”) with fits with three groups (“short”, “long”, and “intermediate”).

Our results indicate that the distributions of observed durations are better fitted by three groups than two groups for *Swift/BAT* data; interestingly, the “intermediate” group appears rather clearly for both observed and intrinsic durations. For *BATSE* data, the statistical test does not prefer three groups over two.

We discuss the results, their possible underlying causes, and reasonable interpretations.

Keywords gamma-rays: bursts, theory, observations
- Methods: data Analysis, statistical, chi-square test

1 Introduction

Gamma-ray bursts (GRBs) have durations ranging from 0.001 to 1000 seconds, with substantial variations in their time profiles, indicating that the sources are very compact ($c\Delta t < 3000$ km). The energy of photons emitted in the band [1 keV to 10 MeV] and the total isotropic energy released in a given event are both huge ($10^{51} - 10^{54}$ ergs).

After the discovery of the afterglow of GRB970228 with BeppoSAX, the extragalactic origin of gamma-ray bursts was confirmed (Costa et al. 1997; van Paradijs et al. 1997). The astounding characteristics that those measurements implied gave strong motivation for researchers to study the phenomenon and its physical features, as it was evidently linked to the universe's most distant regions. Indeed, the farthest GRB observed until now is GRB090429B, which has a redshift $z = 9.4$, as determined by photometric techniques (Cucchiara et al. 2011).

After a large number of bursts had been observed, statistical studies were conducted to classify GRBs, in the aim of finding correlations between their physical characteristics or finding links to other better known

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phenomena such as supernovae. One of these classifications, which we are exploring in this work, is the distribution of GRBs' observed and intrinsic durations.

The classification of GRBs according to their intrinsic properties, i.e. estimated in their own rest frames, is very important to understanding the physics of these phenomena. This task, however, is possible only after having collected a large number of bursts with measured redshifts, such that analyses and statistical tests can be performed. Before enough redshifts became available, classifications were made only on the basis of observed quantities such as the duration of the bursts T_{obs}^{90} during which 90% of the fluence is accumulated.

Using the first BATSE catalog, Kouveliotou et al. (1993) and McBreen et al. (1994) inferred a bi-modal distribution for the logarithm of the duration T_{obs}^{90} . The classification of the distribution of the durations of the GRBs detected by BATSE into three groups was explored by (Horváth 1998; Balastegui et al. 2001; Hakkila et al. 2000a; Horváth 2002; Chattopadhyay et al. 2007). A study by Horváth (2009a) of BeppoSAX GRBs showed a different distribution than previously found for the BATSE bursts. Further research on this classification issue was made on Swift/BAT GRBs and Fermi/GMB GRBs (Horváth et al. 2008; Zhang and Choi 2008; Lin 2009; Qin et al. 2013). A study of the distribution of 1003 GRBs observed by BeppoSAX and given by Frontera et al. (2009a,b) was performed by Horváth (2009b). Comparative studies between the distributions of the burst durations in BATSE and Swift/BAT samples have been made by Huja et al. (2009).

The distribution of intrinsic durations of GRBs was studied by (Zhang and Choi 2008), who used the 95 bursts which then had known redshifts. The authors used statistical tests to determine whether the distribution of burst durations was better fitted with two or three groups. They also compared with data from earlier instruments. One of the goals of our work was to see whether the analysis of the larger sample that we have (248 Swift bursts with well-determined redshifts) would give similar results as those of (Zhang and Choi 2008). We will see that some interesting similarities and differences have appeared.

In presenting our work, we start by explaining our method of sampling and analysis of the data used. Following that, we apply our method by comparing a sample of 2041 GRBs observed by BATSE and a sample of 757 GRBs observed by Swift/BAT. Next, we compare the data from the large Swift/BAT sample with that from a sub-sample consisting of 248 GRBs with known redshifts. The third section is devoted to the study of these three samples by comparing their classification

into two or three groups by duration, using the χ^2 test as a measure. We conclude with a discussion and conclusion.

2 Method

In this work we are interested in three samples of bursts observed by BATSE and Swift/BAT. The first sample consists of 2041 GRBs observed by BATSE and presented in the “Current BATSE Catalog” website¹. The catalog gives: the GRB's number; the burst's duration T_{90}^{obs} ; and the uncertainty over it, ΔT_{90}^{obs} . The second sample consists of all the bursts observed by Swift/BAT until 13.02.2014 for which the duration and the uncertainty attached to it are determined. This second sample is composed of 757 GRBs, for which the data are given on the “Swift Ground Analysis” website². The third sample consists of GRBs from among the second sample that have a known redshift. This third sample is composed of 248 GRBs, the most recent one being GRB140213A.

The durations of the GRBs in the samples vary in the range $[10^{-3}, 10^3]$ seconds. Studying the distribution of bursts according to their durations requires (in principle) dividing the intervals into equal-length bins and filling them with bursts of the corresponding durations. However, the durations vary by six orders of magnitude, and the observed data follow a log-normal distribution. Therefore, it is preferable to use logarithmic binning in order to better study these distributions.

To construct new distributions on the basis of this choice of bins, we adopt a two-stage method.

First, we simulate/reconstruct each sample by Monte Carlo. Indeed, the number of GRBs per bin depends on both the latter's width and the uncertainty over the bursts' durations. To take the uncertainties over the durations into account, we simulate large numbers of GRBs with durations randomly drawn from a normal distribution $f(T)$ centered on each observed duration, $\mu = T_{90}^{obs}$, and characterized by a standard deviation σ corresponding to the given uncertainty ΔT_{90}^{obs} . The normal distribution is given by the expression:

$$f(T) = \frac{1}{\sigma\sqrt{2\pi}} \exp -\frac{(T - \mu)^2}{2\sigma^2}. \quad (1)$$

The burst's duration in each iteration is calculated by using Monte Carlo method according to the expression:

$$T_i = F^{-1}(Y_{Rn}). \quad (2)$$

¹<http://www.BATSE.msfc.nasa.gov/BATSE/grb/catalog>

²http://gcn.gsfc.nasa.gov/swift_gnd_ana.html

The Monte Carlo method is used to draw a random number Y_{Rn} from a uniform distribution between $[0, 1]$ satisfying:

$$F(T) = \int_{-\infty}^T f(T') dT'. \quad (3)$$

The number of iterations depends on the accuracy that we aim for, which is in practice set by the computational speed of our machines and codes. In our work, the number of iterations is 6×10^4 .

Through this method, we reconstructed the first sample, which consists of 2041 *BATSE* GRBs that were observed over 9 years. Furthermore, by increasing the number of simulation values, this method can smooth the distribution of bursts' durations. In Fig.1 we present the result of this method for the *BATSE* sample, with a logarithmic bin of 0.3. In Fig.2, we present the same results with a bin of 0.2 in the aim of showing the effect of the choice of the width of this parameter on the distribution. Comparing (Fig.1) and Fig.2, we note that the choice of the width of the bin is important for the study of each distribution.

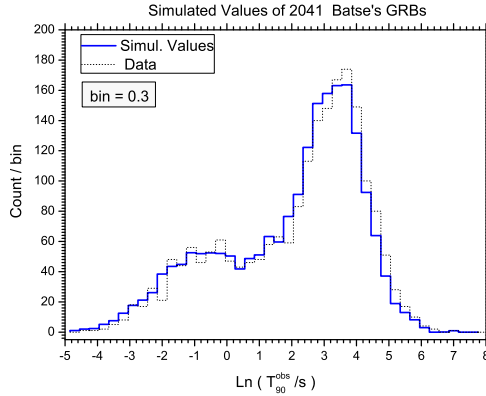


Fig. 1 Comparison between the distribution of observed durations for *BATSE* GRBs and that obtained using our Monte Carlo simulation of the same sample. In this case the bin has a width of 0.3.

Moreover, the different total number of bursts N_0 in each of the three samples that we will be analyzing will not allow us to make direct comparisons between the different distributions. To address this problem, we use a method of standardization to bring all the distributions to the same scale:

$$g(T) = \frac{1}{N_0} \frac{dN}{d(\ln T)}. \quad (4)$$

This second step in our method thus produces a function $g(T)$ which represents a probability density.

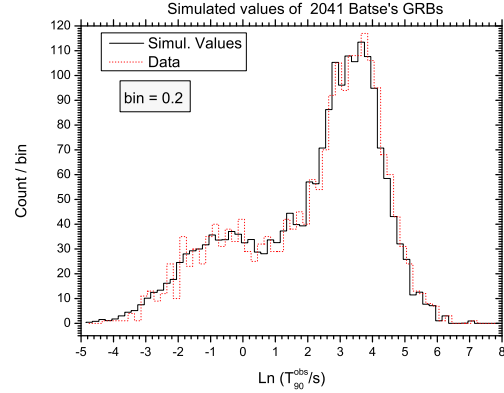


Fig. 2 Comparison between the distribution of observed durations for *BATSE* GRBs and that obtained using our Monte Carlo simulation of the same sample. In this case the bin has a width of 0.2.

We then use this expression for the 757 *Swift/BAT* GRBs of our second sample taking bin widths of 0.2, 0.3, and 0.4. We note from Fig.3 that the resulting distribution profile is independent of the choice of the bin.

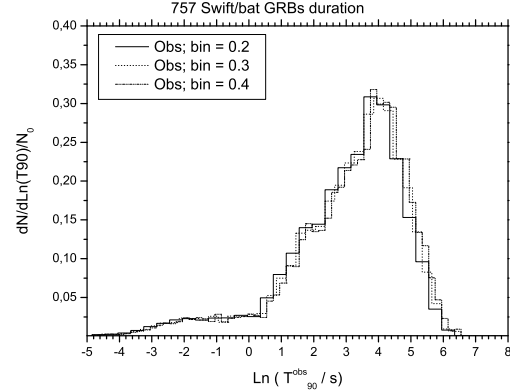


Fig. 3 Normalized distributions of observed durations for *Swift/BAT* bursts and for the sample obtained using our Monte Carlo simulation, for bin widths = 0.2, 0.3 and 0.4.

3 Comparison between *BATSE* GRBs and *Swift/BAT* GRBs

In Fig.3 one can readily note that *Swift/BAT* detects fewer SGRBs (short bursts) compared to *BATSE*. *Swift/BAT* has higher sensitivity and angular resolution than *BATSE*, *BeppoSAX*, and *HETE-2*. However, it is less sensitive to SGRBs than *BATSE* (8%

vs. 18%). This is due mainly to its energy range [15–150 keV] since SGRBs have relatively harder spectra (Band 2006; Kaneko et al. 2006; Gehrels et al. 2007). Moreover, *Swift*/*BAT* GRBs show a clear(er) bump in their distribution of durations between 2 and 10 sec compared to the *BATSE* data. This same bump also appears in the distribution of durations of 1003 GRBs observed by *BeppoSAX* (Frontera et al. 2009b; Horváth 2009b), which also observed few SGRBs (112) compared to LGRBs (891).

4 Study of the Intrinsic Durations

It is very important to characterize GRBs by their intrinsic properties, as these relate to the physical processes that produce the phenomenon. In relation to this, we may mention the correlations between the isotropic energy E_{iso} , peak energy of the spectrum $E_p^s = E_p^{obs} \times (1+z)$, the isotropic luminosity L_{iso} , and the total collimated energy E_γ (Amati et al. 2002; Amati 2006; Yonetoku et al. 2004; Ghirlanda et al. 2006; Nava et al. 2012; Zitouni et al. 2014) and others. The study of these relationships was possible only after the determination of the GRBs’ redshifts.

In this section, we are interested in the study of the distribution of intrinsic *Swift*/*BAT* GRB durations. Except for Zhang and Choi (2008), this relationship has not been examined before due to the low number of GRBs with known redshifts. For this purpose, we constructed a third sample, which consists of 248 GRBs whose redshifts and durations have been determined. The intrinsic duration, denoted T_{90}^s , represents the duration of the GRB in its inertial frame and is inferred from the observed duration via the expression:

$$T_{90}^s = \frac{T_{90}^{obs}}{1+z}. \quad (5)$$

In the sample of *Swift*/*BAT* GRBs with known redshifts, we must note that the distribution of redshifts is not the same for short and long bursts. For SGRBs, the median of earlier samples of the redshift distribution was 0.4 (Norris and Bonnell 2006; O’Shaughnessy et al. 2008; Horváth et al. 2008; Zhang and Choi 2008), while for LGRBs, the median was 2.4 (Bagoly et al. 2006; Horváth et al. 2008). In our sample, the median of the redshift distribution for short bursts is 0.78 ± 0.70 , while for long bursts it is 2.13 ± 1.35 . (The difference in the values is due to our use of a much larger number of GRBs with redshifts compared to what these authors used.)

This difference between the redshifts of SGRBs and LGRBs tends to blur the “boundary” between the durations of the two groups, a “boundary” traditionally thought to be at 2 s. With an average redshift of 2, “long” bursts with observed durations less than 6 seconds will have an intrinsic duration below 2 seconds, while short observed bursts of any redshift will remain short in terms of intrinsic duration.

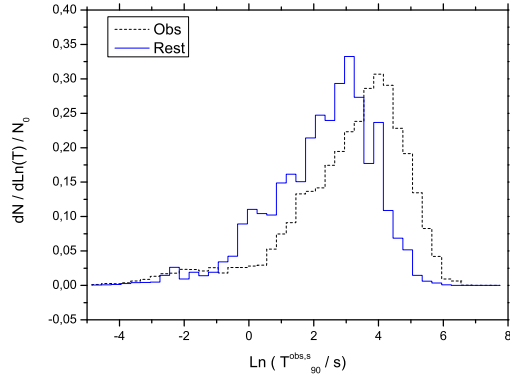


Fig. 4 Comparison between the normalized distribution of observed durations and intrinsic durations for 248 *Swift*/*BAT* GRBs.

In Fig.4 we have represented the two normalized distributions for observed durations T_{90}^{obs} and intrinsic durations T_{90}^s . Note that the distribution of intrinsic durations is similar to that of the observed durations, with a general shift to the left of most of the distribution. The area or boundary that seemed to clearly separate the two populations in the *BATSE* sample is almost absent in the *Swift*/*BAT* sample. Likewise, in the distribution of intrinsic durations, the clear separation between the short and the long bursts tends to disappear.

5 Search for “Intermediate” Duration Group

The various studies done on the distributions of GRB durations that we mentioned in the introduction revolved around determining the groups that the observed durations of GRBs seemed to fall under in different samples. In the present work, we are interested in reviewing the groups that GRBs have been categorized under, in the *BATSE* and the *Swift*/*BAT* catalogs; in particular, we are interested in searching for a third, “intermediate” population of bursts, between the SGRBs and the LGRBs. For this purpose and for each sample, we perform a statistical comparison between a given set of data and either two or three Gaussian distributions.

The first step is to fit a given set of data (*BATSE*, *Swift/BAT*, observed durations, calculated intrinsic durations) using log-normal functions. The goal is to get the three parameters used in the Gaussian functions (mean, peak, and standard deviation values) for a best fit. For a fit with two groups (or classes), we need six parameters, and for three groups (or classes) we need nine parameters. We have adopted the minimization of χ^2 as a way to determining the parameters for a best fit in each case (Baker and Cousins 1984; Hauschild and Jentschel 2001; Press et al. 1989; Zwillinger and Kokoska 2010; Saporta 2011; Martin 2012).

The χ^2 is defined as:

$$\chi^2 = \sum_{i=1}^n \frac{(O_i - E_i)^2}{E_i}, \quad (6)$$

where O_i is the observed value and E_i is the expected value in the i bin. We use $n = 43$ bins for the three samples that we study below. The degree of freedom $\nu = n - k - 1$, where k is the number of parameters for each model.

The probability density function of the χ^2 distribution with ν degrees of freedom is defined in $[0, +\infty]$ as:

$$f(\chi^2) = \frac{1}{2^{\nu/2} \Gamma(\nu/2)} \exp\left[-\frac{1}{2}\chi^2\right] (\chi^2)^{\frac{\nu}{2}-1}. \quad (7)$$

The probability that the observed χ^2 for a correct model should be less than a critical value, χ_c^2 , with ν degrees of freedom is :

$$P(\chi^2 | \nu) = \int_0^{\chi_c^2} f(\chi^2) d\chi^2, \quad (8)$$

Its complement, called "p-value", is the probability that the observed χ^2 will exceed the critical value χ_c^2 (Saporta 2011; Martin 2012):

$$\text{p-value} = 1 - P(\chi^2 | \nu) = \int_{\chi_c^2}^{+\infty} f(\chi^2) d\chi^2. \quad (9)$$

It is defined by Martin (2012) as the smallest level of significance that would lead to a rejection of the null hypothesis using the observed sample, or the probability of getting from the statistical test a value that contradicts the null hypothesis at least as much as for computed from the sample. P-values are thus often coupled to a significance level or α , which is also set ahead of time, usually at 0.05, 0.01, or even smaller (Martin 2012).

We apply our method involving the probability density distribution functions so that the statistical properties of each sample are preserved, and the fitting param-

eters (μ et σ) are generic. We use log-normal functions for these fits, so the fits can be written as

$$\frac{1}{N_0} \frac{dN}{d \ln T} = \sum_{i=1}^n A_i \exp -\frac{(\ln T - \mu_i)^2}{2\sigma_i^2}, \quad (10)$$

where A_i is the amplitude or the maximum height of each group, σ_i is the "width" of the group, μ_i is the "position" (center) of the group, and n is the number of groups.

In Fig.5a and Fig.5b we display the fits of the distribution of observed durations by considering two or three groups.

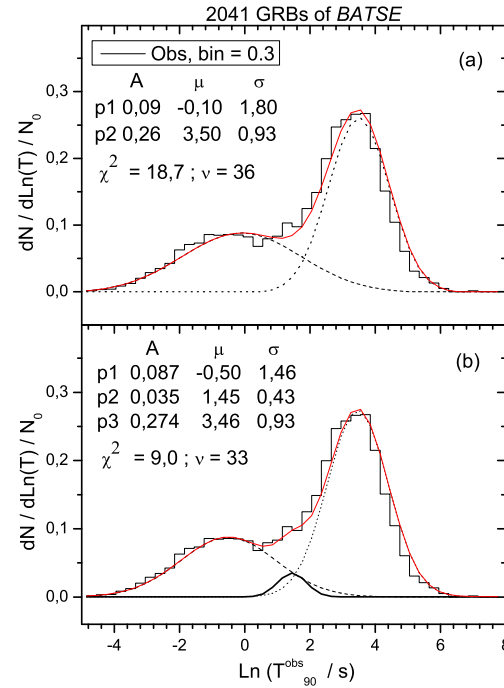


Fig. 5 *BATSE* normalized distribution of GRBs observed durations. The χ^2 is calculated before normalisation. p_1 , p_2 and p_3 correspond to the first, second and third peaks. (a): Data fitted with two lognormal functions. (b): Data fitted with three lognormal functions.

For *BATSE* observed durations, the minimum values for χ^2 obtained are 18.7 for two groups and 9.0 for three groups. The parameters of each peak are shown in Fig.5.

Tab.1 gives the positions of the centers of each group as obtained in this work, alongside those of Horváth (2002). The results are in good agreement.

	$T_{90,m}^{obs}$ (s)	
	This work	Ref. ^a
p1	$0.99^{+0.11}_{-0.09}$	0.78
p2	$33.11^{+0.67}_{-0.65}$	34.67
p1	$0.61^{+0.06}_{-0.06}$	0.56
p2	$4.26^{+0.36}_{-0.33}$	4.26
p3	$31.82^{+0.55}_{-0.54}$	35.48

Table 1 Centers of the two- and three-group fits of the *BATSE* burst durations. (a): Horváth (2002);

We apply the same method (minimization of χ^2) for our sample of *Swift*/*BAT* bursts, again fitting the distribution of observed durations. The minimum values for χ^2 obtained are 6.0 for three groups and 52.4 for two groups. The results are shown in Fig.6a and Fig.6b.

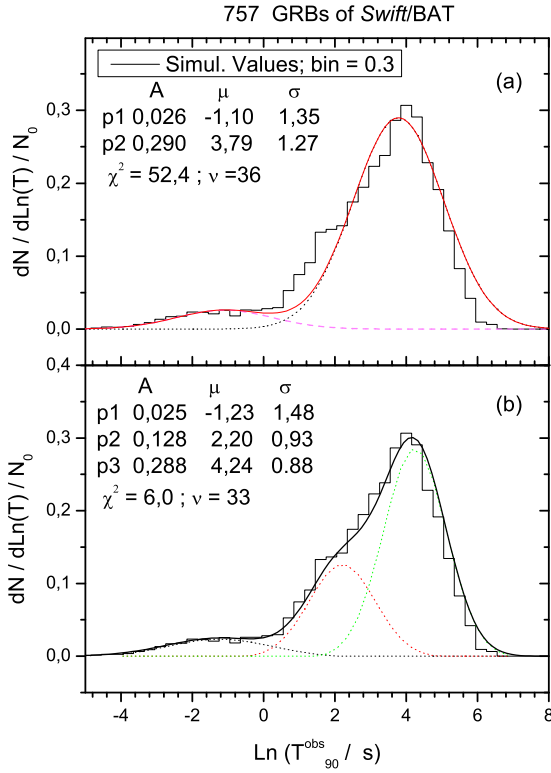


Fig. 6 *Swift*/*BAT* normalized distribution of GRBs observed durations. The χ^2 is calculated before normalisation.

Tab.2 gives the positions of the centers of each group, as obtained in this work, alongside those of Horváth (2002). The results are in good agreement for the model with three groups.

The final sample of GRBs studied here consists of 248 *Swift*/*BAT* GRBs with known redshifts. We ap-

	$T_{90,m}^{obs}$ (s)		$T_{90,m}^s$ (s)	
	This work	Ref. ^b	This Work	Ref. ^c
p1	$0.33^{+0.13}_{-0.09}$	0.35	$0.13^{+0.05}_{-0.03}$	0.13
p2	45^{+2}_{-3}	40.36	$16.4^{+1.2}_{-1.1}$	12.30
p1	$0.29^{+0.13}_{-0.09}$	0.34	$0.11^{+0.05}_{-0.03}$	
p2	$9.06^{+1.42}_{-1.23}$	12.79	$2.56^{+1.49}_{-0.94}$	
p3	$69.72^{+4.92}_{-4.59}$	79.98	$25.0^{+4.2}_{-3.6}$	

Table 2 Centers of the two- and three-group fits of the *Swift*/*BAT* bursts. (b):Horváth (2009a); (c): Zhang and Choi (2008)

plied the same method, i.e. fitting theoretical lognormal functions to the intrinsic durations data (i.e. as calculated in the GRBs' source frames). The minimum values for χ^2 obtained are 39.6 for two groups and 15.3 for three groups. The main results are presented in Fig.7a and Fig.7b. Tab.2 (last two columns) gives the positions of the centers of each group, as obtained in this work (with 248 GRBs), alongside those of Zhang and Choi (2008) (with 95 GRBs), for the two-group fits only.

Some authors have used the p-value as a measure of the goodness of the fit (Hauschild and Jentschel 2001; Press et al. 1989; Press et al. 2007). If p-value > 0.1 , the model can be accepted; if p-value < 0.001 , the model is very likely to be wrong. We do not adopt that kind of approach; instead of follow the method outlined below.

The second step is to perform a statistical test to compare between the model of two groups (2g: short and long durations) with the model of three groups (3g: short, intermediate and long durations). To perform this test we follow the method used by Band et al. (1997) and Horváth (1998), a method which is well explained in Balakrishnan et al. (1999).

We calculate $\Delta\chi^2(\nu) = \chi_{2g}^2(\nu_1) - \chi_{3g}^2(\nu_2)$ for each sample of data. The degree of freedom is $\nu = \nu_1 - \nu_2$. Our null hypothesis here is that the data is well represented by two groups. We adopt a critical value of 0.001 for α : if $\Delta\chi^2 < \chi_{0.001}^2$ or (p-value > 0.001), then the data is fitted with two groups at a significance level of 0.001. In all samples, $\nu = 36 - 33 = 3$, then $\chi_{0.001}^2$ is equal to 16.27. This value is compared to those obtained ones for each sample of data (*BATSE*, *Swift*/*BAT*, observed and intrinsic) presented in the Table (3) with their corresponding p-values.

From these results (Table 3), we conclude that the null hypothesis is accepted for the *BATSE* data. Therefore, the *BATSE* data are well represented by two groups or populations of gamma-ray bursts, as was originally suggested before by Kouveliotou et al. (1993). On the contrary, for *Swift*/*BAT* data (both intrinsic

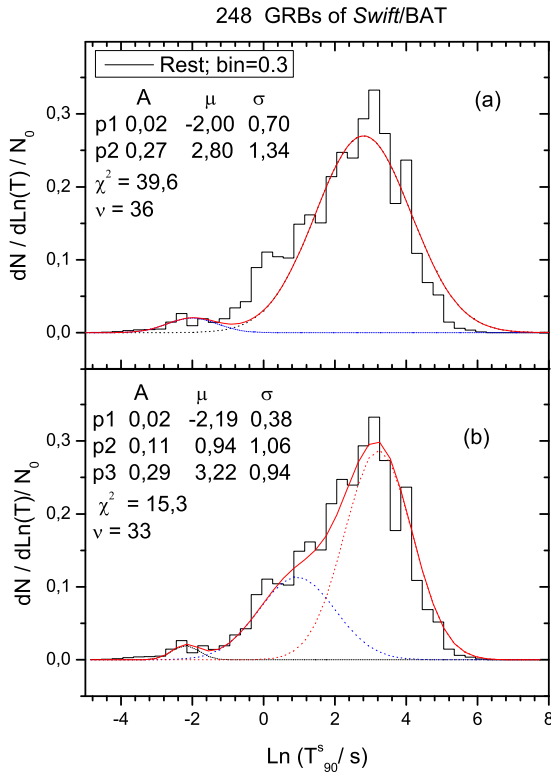


Fig. 7 *Swift/BAT* normalized distribution of GRBs intrinsic durations. The χ^2 is calculated before normalisation.

and observed), the model of two groups (short and long durations distributions) is clearly rejected by the statistical test with a p-value less than $3 \cdot 10^{-5}$.

6 Discussion

GRBs have widely been classified into two categories: short ones (SGRBs) and long ones (LGRBs), separated at $T_{90}^{obs} = 2$ sec, following a classification by Kouveliotou et al. (1993) of *BATSE* GRBs. However, GRBs observed by different instruments spread out into roughly log-normal distributions that more or less overlap.

Our present work shows that the distribution of *BATSE* GRBs' observed durations can be better fitted by two groups than three groups; that is, the *BATSE* bursts can be, statistically, categorized into two classes better than three classes. In some previous work (Hakkila et al. 2000b,c; Meegan et al. 2000), it has been reported that this intermediate group is due to the selection effect of the *BATSE* instrument. And indeed, It has been therefore difficult to present GRBs

	$\Delta\chi^2$	p-value	Decision
BATSE	9.7	$2.1 \cdot 10^{-2}$	H0
Swift/Obs	46.6	$4.7 \cdot 10^{-10}$	H1
Swift/Rest	24.3	$2.16 \cdot 10^{-5}$	H1

Table 3 H_0 is the null hypothesis : $\Delta\chi^2 < 16.27$ or p-value > 0.001 ; H_1 is the alternative hypothesis.

of intermediate durations as a well-specified category (Bromberg et al. 2013).

For *Swift/BAT* observed durations, however, our statistical analysis method shows a clear preference for a model with three classes over one with two, with an intermediate class appearing at durations in the range of 2 - 10 seconds. In fact, it is worth noting that the intermediate class has a stronger presence than the (traditional) short one, even if we limit the fit to two groups. This was also true for the *BeppoSAX* bursts studied by Horváth (2009a).

For *Swift/BAT* intrinsic durations, the results of our study clearly shows a preference for the class of intermediate duration over the short one, even in the two-group model. However, the statistical test prefers the hypothesis of fitting the data with three groups instead of two.

The classification of GRBs into two or three groups should in principle be linked to intrinsic differences in the bursts, to their mechanisms of production, and to their origins. SGRBs are generally understood to be the result of a merging of two compact objects (two neutron stars or one neutron star and one black hole) and LGRBs are associated with collapses of hyper-massive stars ("Collapsars"). A third group of only six GRBs, characterized by a low luminosity ($L < 10^{49}$ erg/s), has been shown not to fit in either of these two classes (Bromberg et al. 2013). These authors have also shown that the division at $T_{90} \approx 2$ seconds between Collapsars (long bursts) and non-Collapsars (short burst) can no longer be ascertained, as 40 percent of Swift's bursts of duration less than 2 seconds are in fact Collapsars; moreover, a non-negligible fraction of those have durations less than 0.5 seconds; likewise, a number of non-Collapsars have durations longer than 10 seconds. Bromberg et al. (2013) suggest a division between the two groups at 0.8 seconds as more suitable for *Swift/BAT*.

Our results also indicate a difference between the distributions of durations presented by the *BATSE* and *Swift/BAT* detecting instruments, which implies that the detectors do significantly affect the categorization of bursts. The relative dearth of SGRBs in the *Swift/BAT* sample may be due to the energy band (15 - 150 keV) in which the detector operates, especially since SGRB

photons are characterized by relatively hard spectra. The same thing can be seen in the distribution of GRBs from *BeppoSAX*, which had operated in the 40 - 700 keV energy band.

Finding a statistically significant intermediate class of bursts, Horváth et al. (2008) believe that the group is distinct and real; in fact, they find distinctive physical features for these bursts: in particular, 99.9 % in logH43 and logH32 hardnesses and anisotropic sky distribution (Mészáros et al. 2000; Litvin et al. 2001). These researchers also recall that this intermediate class had been found in *BATSE* bursts by a number of other researchers, starting with Mukherjee et al. (1998).

On the other hand, one should note that finding evidence of a third log-normal component in the analysis of the burst duration distribution does not necessarily imply the existence of a third physical channel for the production of GRBs, in addition to the merger and collapsar mechanisms. Indeed, the durations distribution corresponding to the collapsar scenario has no reason to be exactly symmetric in $\text{Log}(T_{90})$. If, for example, we link the duration of a burst to the amount of mass that can be accreted by the newly formed black hole, the durations distribution may reflect the distribution of envelope masses of the progenitors. If this distribution is asymmetric, with more massive progenitors being less common, a “shoulder” may appear in the durations distribution. This shoulder would result in a preferred three-group fit of the data without imposing a new physical mechanism of burst formation.

7 Conclusion

In this work we set out to study the existence of a third, intermediate class of bursts between the short-duration and long-duration ones. The non-symmetric shape of the distribution of long-duration GRBs seen in the *Swift/BAT* data (a “shoulder” on the lower side of the distribution) motivated us to search for a separate group in the zone between 2 and 10 seconds.

Indeed, the χ^2 statistical test favors a distribution with three groups in *Swift/BAT* data, where the third class of bursts appears rather clearly, contrary to the *BATSE* data. Converting to intrinsic durations does not strongly modify the general shape of the (*Swift/BAT*) distribution.

The reality of a third, distinct class of bursts, with different physical mechanisms, features, and sources, is far from established. As we mentioned, besides the issue of detector characteristics and their impact on the types of bursts that are observed and recorded, the work

of Bromberg et al. (2013) has shown that the two traditional classes (Non-Collapsars, i.e. Mergers, producing “short” bursts with durations less than 2 seconds, and Collapsars, producing “long” bursts with durations longer than 2 seconds) is no longer tenable. There are short Collapsars and long Mergers. Perhaps the “intermediate” class that our (and others’) statistical analyses indicate is simply underscoring this overlap between the two types. One conclusion that seems inescapable is that the division at 2 seconds is untenable.

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